AFRICAN DUST OUTBREAKS

A satellite perspective of temporal and spatial variability over the tropical Atlantic Ocean

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OUTLINES

1. Datasets

2. African dust outbreaks: climatology & definition

3. Trajectory analysis

4. Vertical structures

5. Meteorological fields across dust fronts

6. Conceptual diagrams

7. Summary and discussions

DATA

1. Aqua MODIS Dark Target and Deep Blue Aerosol Optical Depth (AOD) (2003-2007)

2. Aqua AIRS Water Vapor Mass Mixing Ratio (MMR) and Relative Humidity (RH) Profiles and temperature profile, surface pressure (2003-2007)

3. NCAR/DOE reanalysis wind fields

4. Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) vertical feature mask product

Outbreaks: climatology

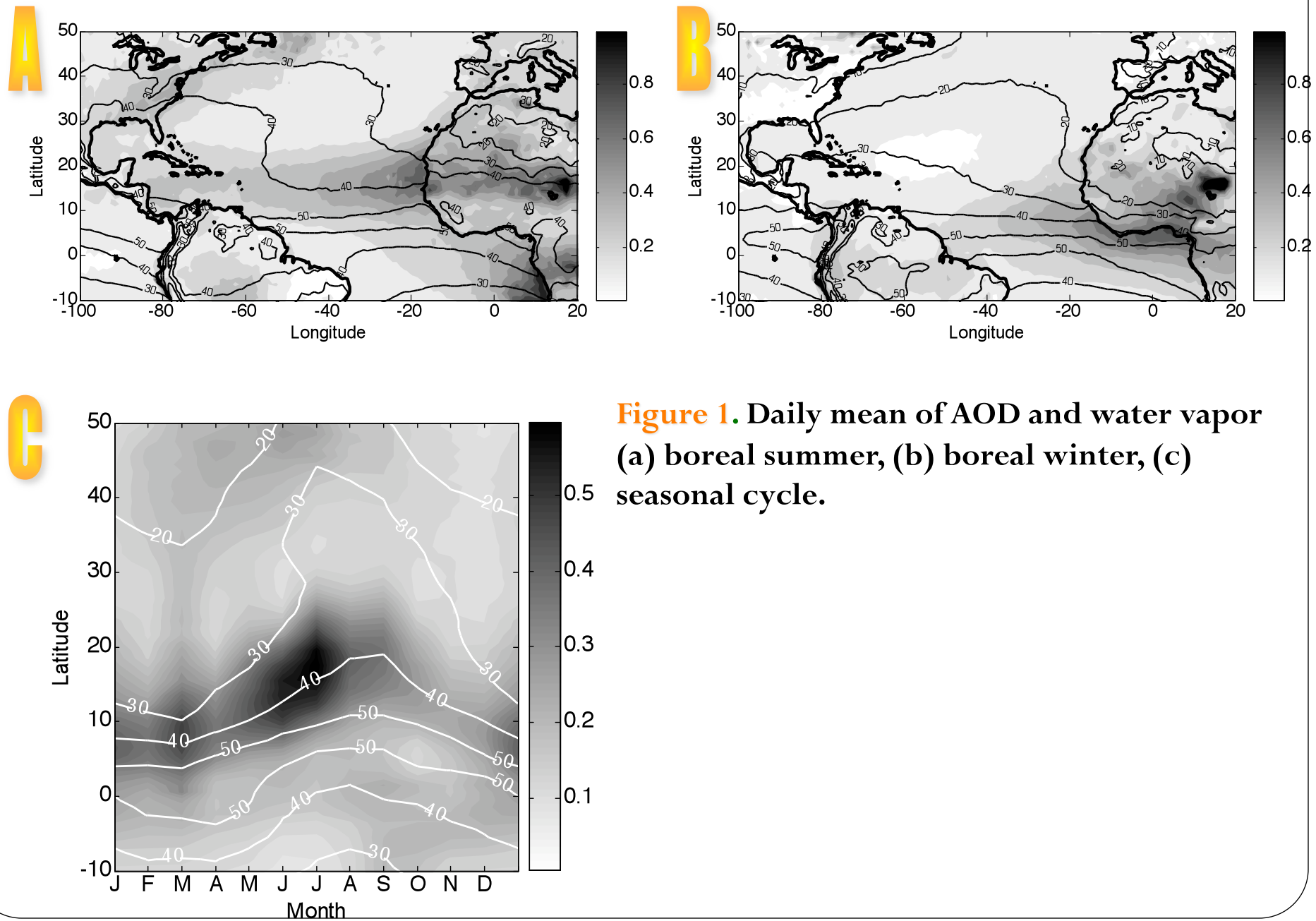


Figure 1. Daily mean of AOD and water vapor (a) boreal summer, (b) boreal winter, (c) seasonal cycle.

Outbreaks: Case Study

July 13-18, 2007

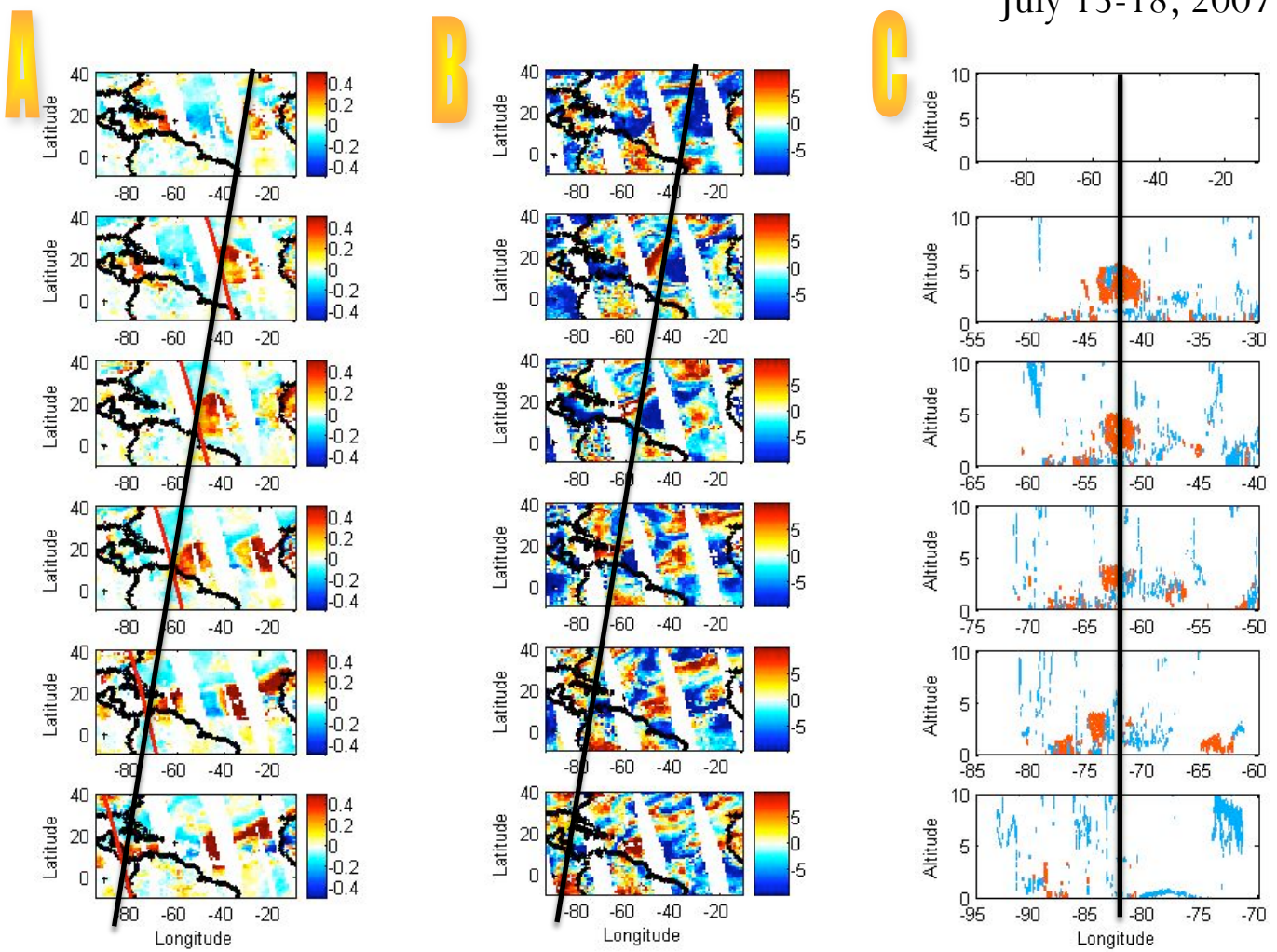
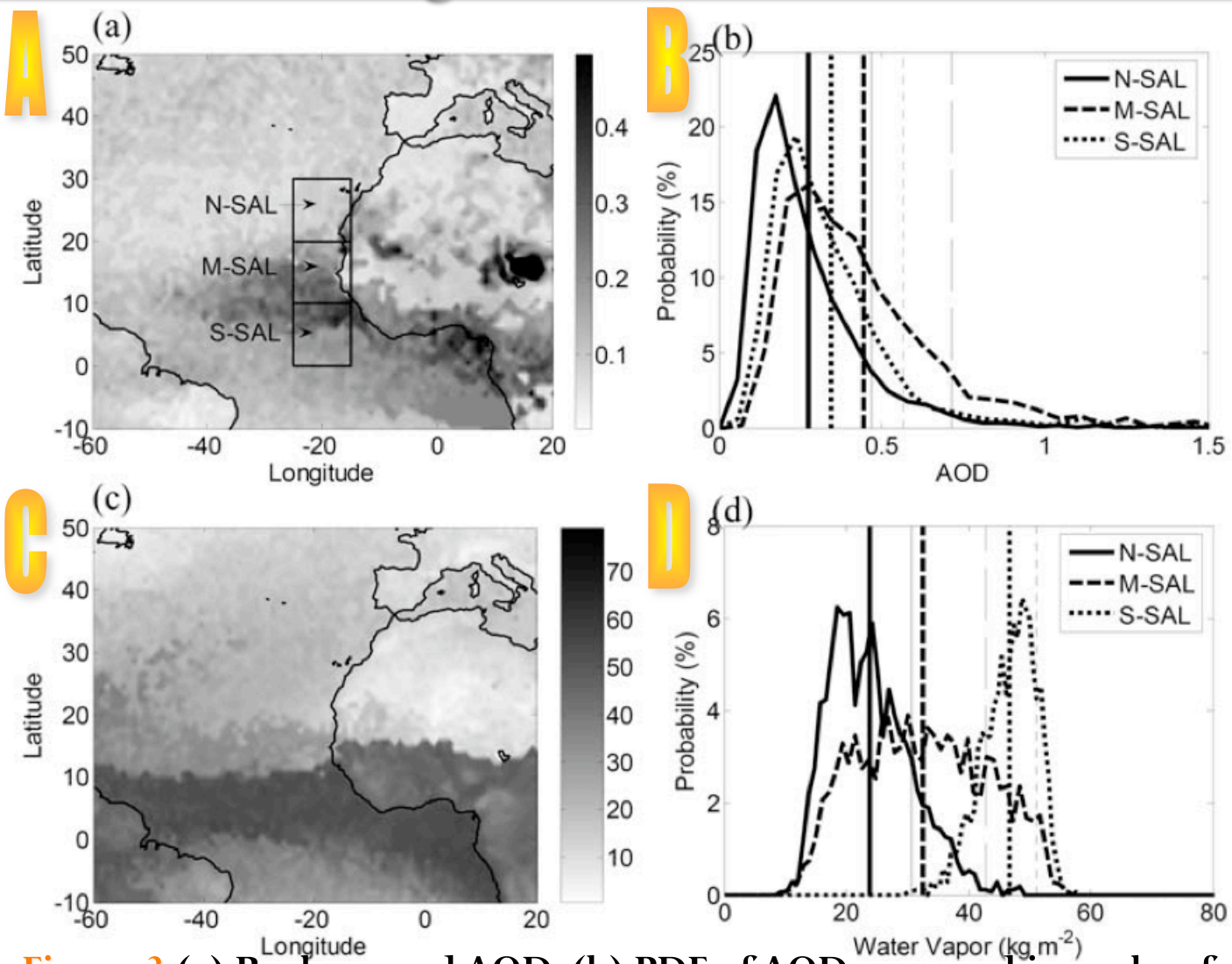


Figure 2. African dust event 13-18 July 2007: (a) AOD anomaly; (b) water vapor anomaly (kg m-2); (c) longitude and altitude of dust layer from CALIPSO.

In the example case, the AOD anomalies are associated with dry air anomalies, traveling westernwards with an approximate speed of 10° longitudes per day.

Outbreaks: Background and Outbreak definition



Only **9%** of dust outbreaks qualified as dry-air out-break days and only **23%** of dry-air outbreaks as dust out-breaks. However, about **54%** of identified dust outbreak days were associated with air drier than the background and about **46%** of dry air outbreaks were associated with dust concentrations greater than the dust background level.

Figure 3.(a) Background AOD; (b) PDF of AOD averaged in each reference box; (c) background water vapor (kg m^{-2}), and (d) PDF of water vapor (kg m^{-2}) averaged in each reference box. Background is defined as the peak values in the PDF. Dust outbreaks are identified when dust AOD is higher than background AOD by one standard deviation.

Trajectory: Statistical Approach

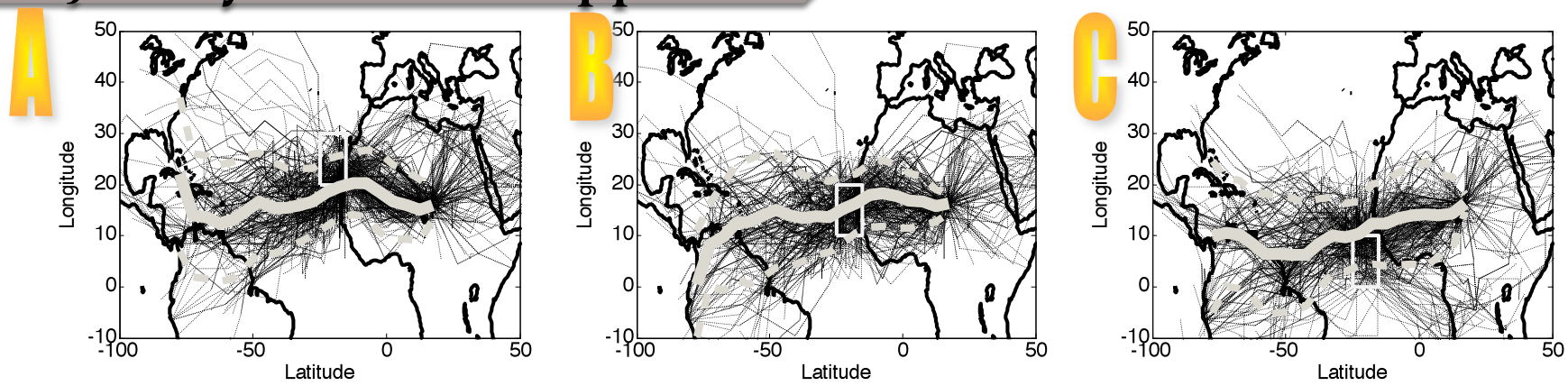


Figure 4. Pathways of all outbreaks passing through reference box of (a) N-SAL; (b) M-SAL; and (c) S-SAL. Central pathways and 75% inclusion lines on both sides of central pathways are in solid and dashed grey lines respectively.

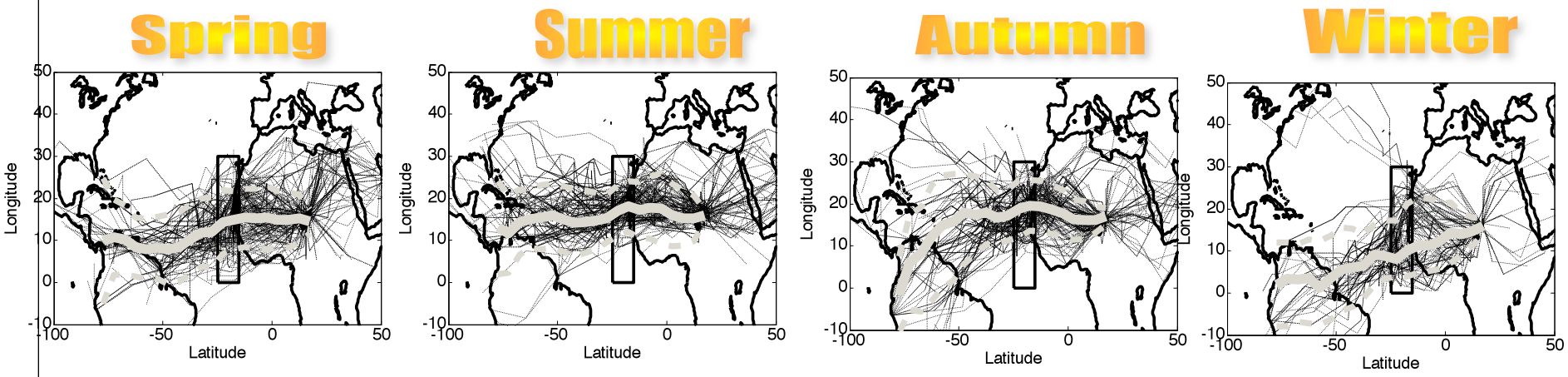


Figure 5. Pathways of all outbreaks in four boreal seasons

Trajectory: Statistical Approach

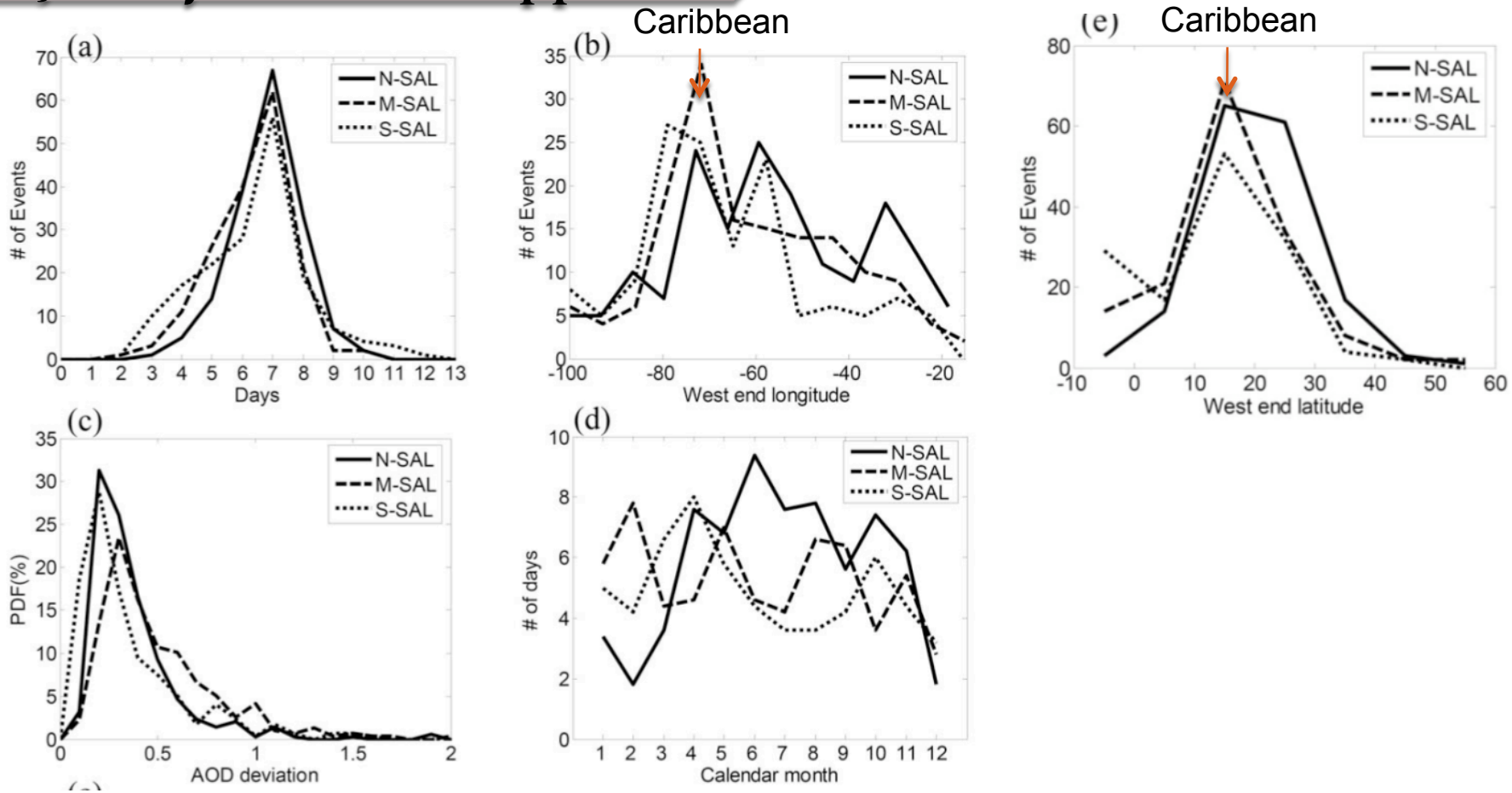
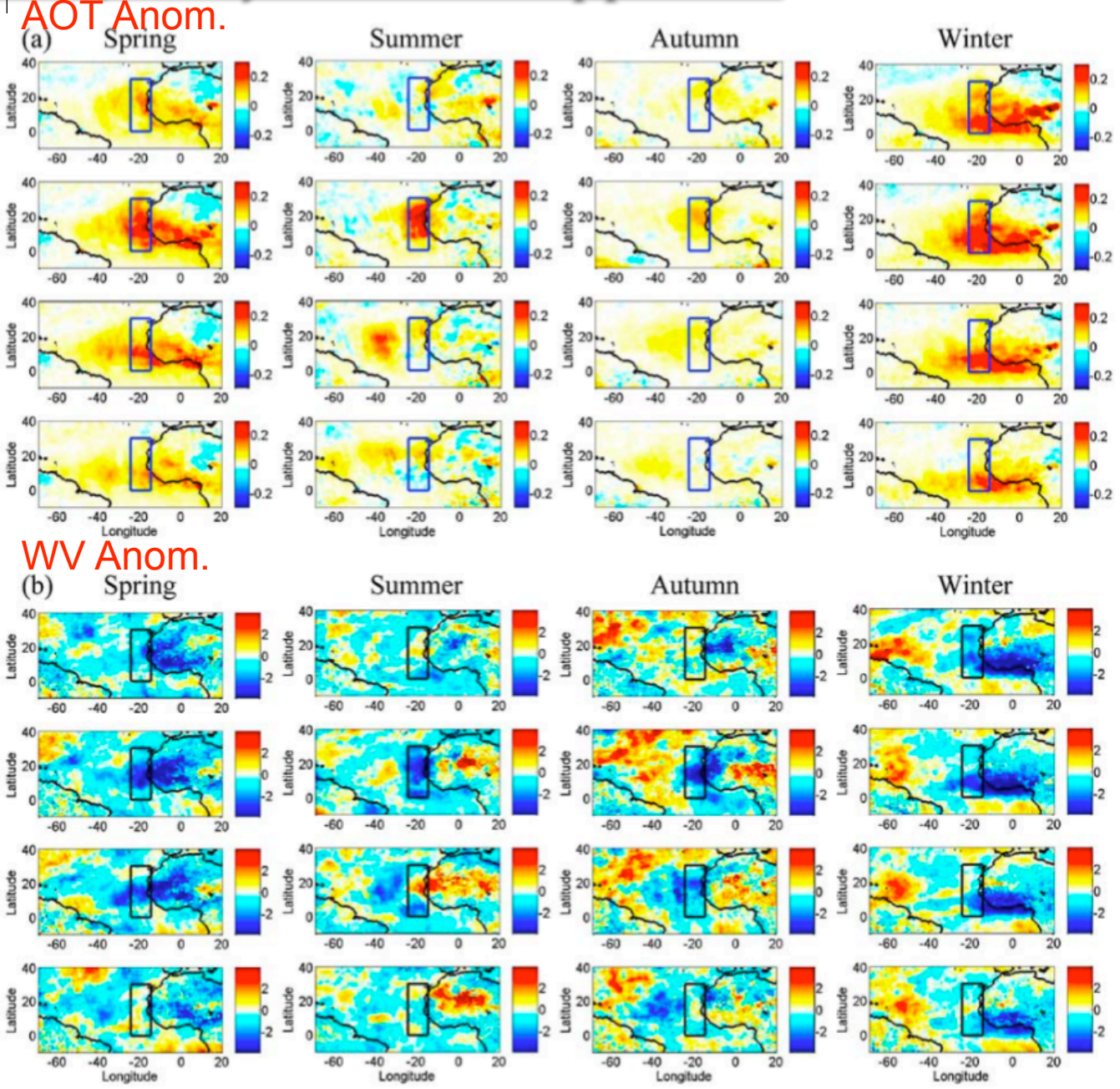


Figure 6. (a) Life span of dust events over the tropical Atlantic, (b) west end longitudes of dust events, (c) PDF of AOD deviation above background AOD for all dust events, (d) annual cycles of dust event days per month, and (e) west end latitude distributions of all events in three reference boxes.

Trajectory: Statistical Approach



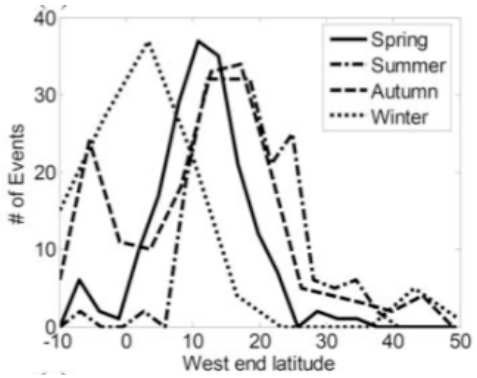


Figure 7. (a) Composites of AOD anomalies for outbreaks within the zone of 75% of pathways (see the text and Figure 8) in four seasons and (b) composites of water vapor anomalies (kg m−2) for the same outbreaks as in Figure 9a in four seasons.

Trajectory: HYSPLIT

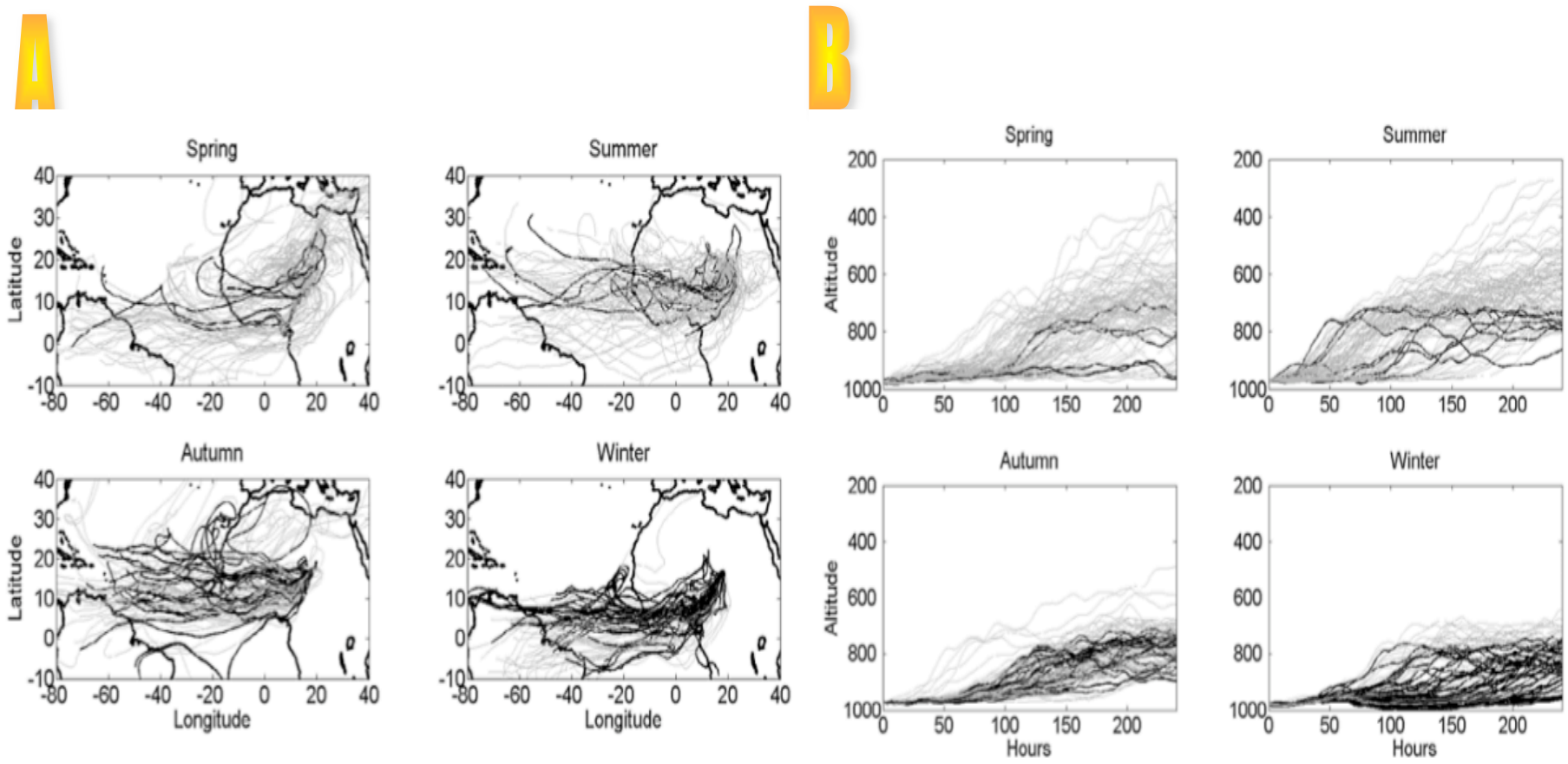


Figure 8. Ten day forward trajectories of air masses staring from the Bodélé Depression (17°N, 18°E) in four seasons: (a) horizontal trajectories and (b) vertical time trajectories. Trajectories reaching altitudes above the 700 hPa level are plotted as gray lines.

Vertical profile: CALIPSO

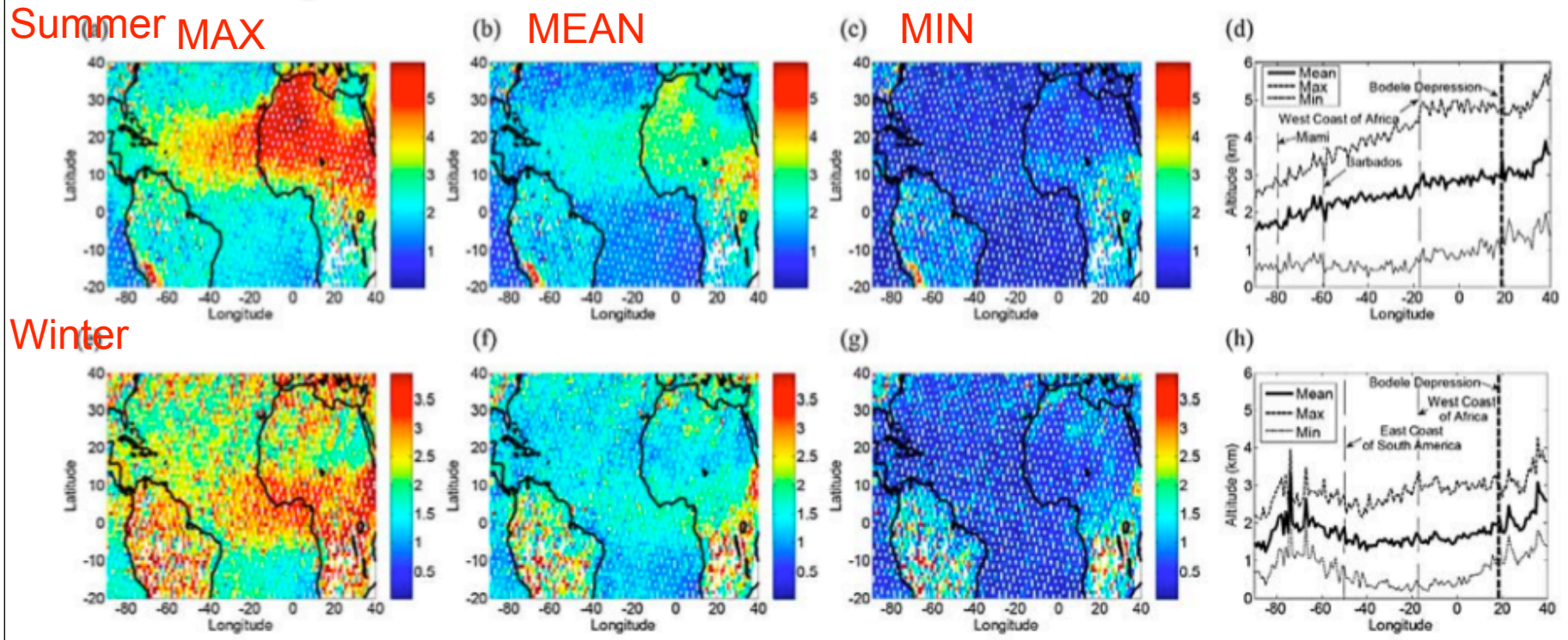


Figure 9. Mean altitude of dust layers based on the CALIPSO vertical feature mask data: (a) top alti- tude (km) in boreal summer, (b) mean altitude (km) in boreal summer, (c) bottom altitude (km) in boreal summer, and (d) mean, maximum, and minimum of the altitude profiles meridionally averaged over 5°N– 25°N in boreal summer. (e–g) Same as Figures 12a–12c but for boreal winter. (h) Same as Figure 12d but averaged over 5°S–15°N in boreal winter. The longitudinal locations of the western coast of Africa and the Bodélé Depression are marked by a thin vertical dashed line and a heavy dashed line, respectively; western Atlantic locations are similarly marked.

Meteorological fields across dust fronts

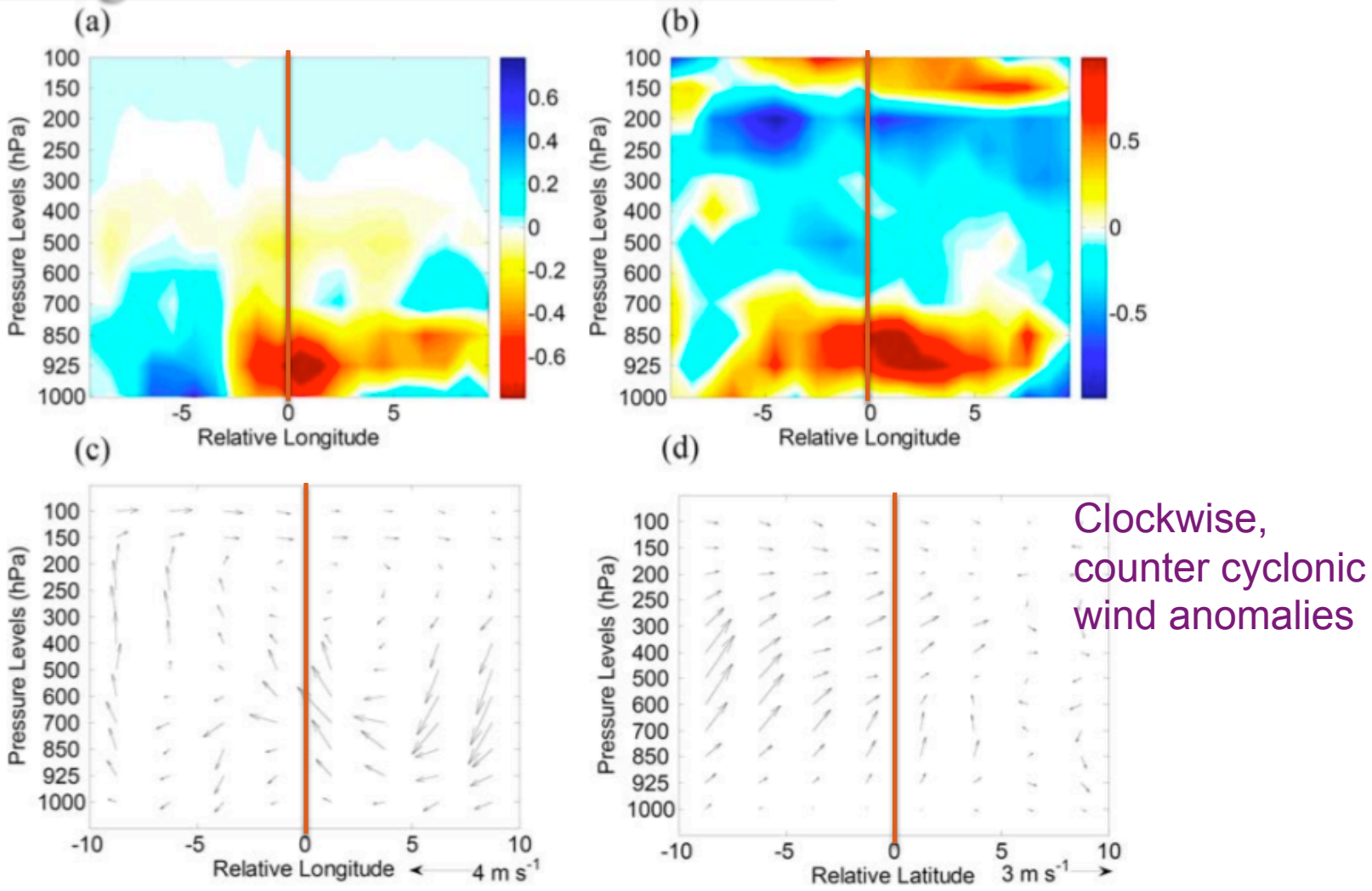


Figure 10. Composites of anomalies of (a) water vapor mixing ratio (g kg−1), (b) temperature (K), (c) zonal and vertical wind, and (d) meridional and vertical wind across dust fronts. Zero longitude or latitude represents the location of a dust front.

Conceptual Diagrams

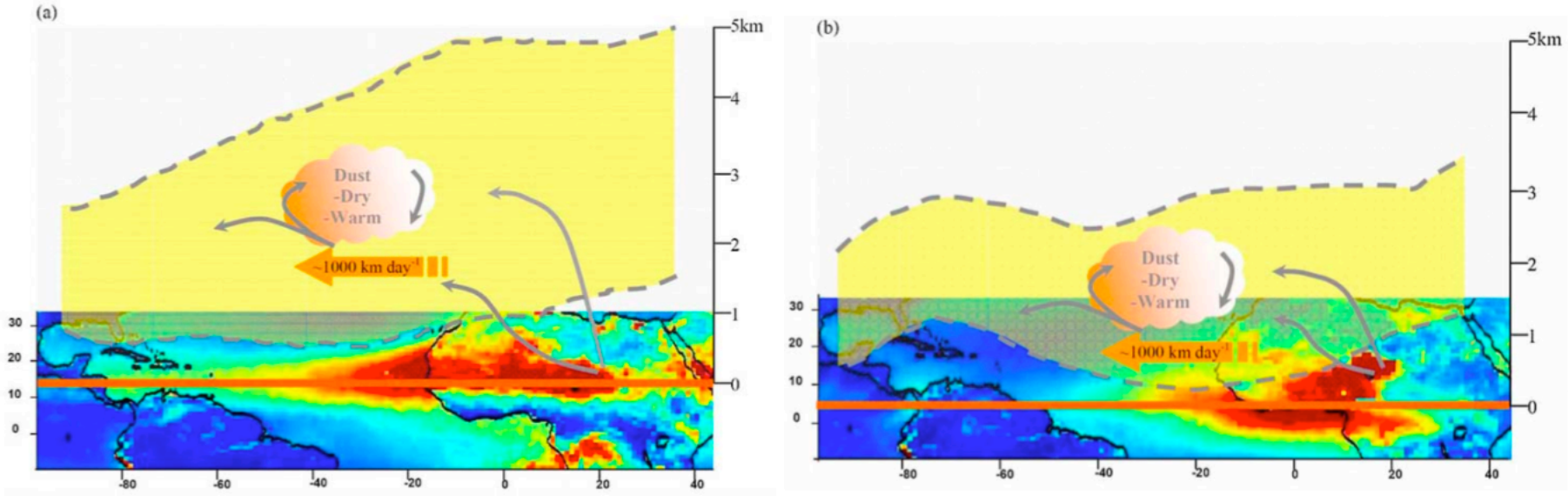
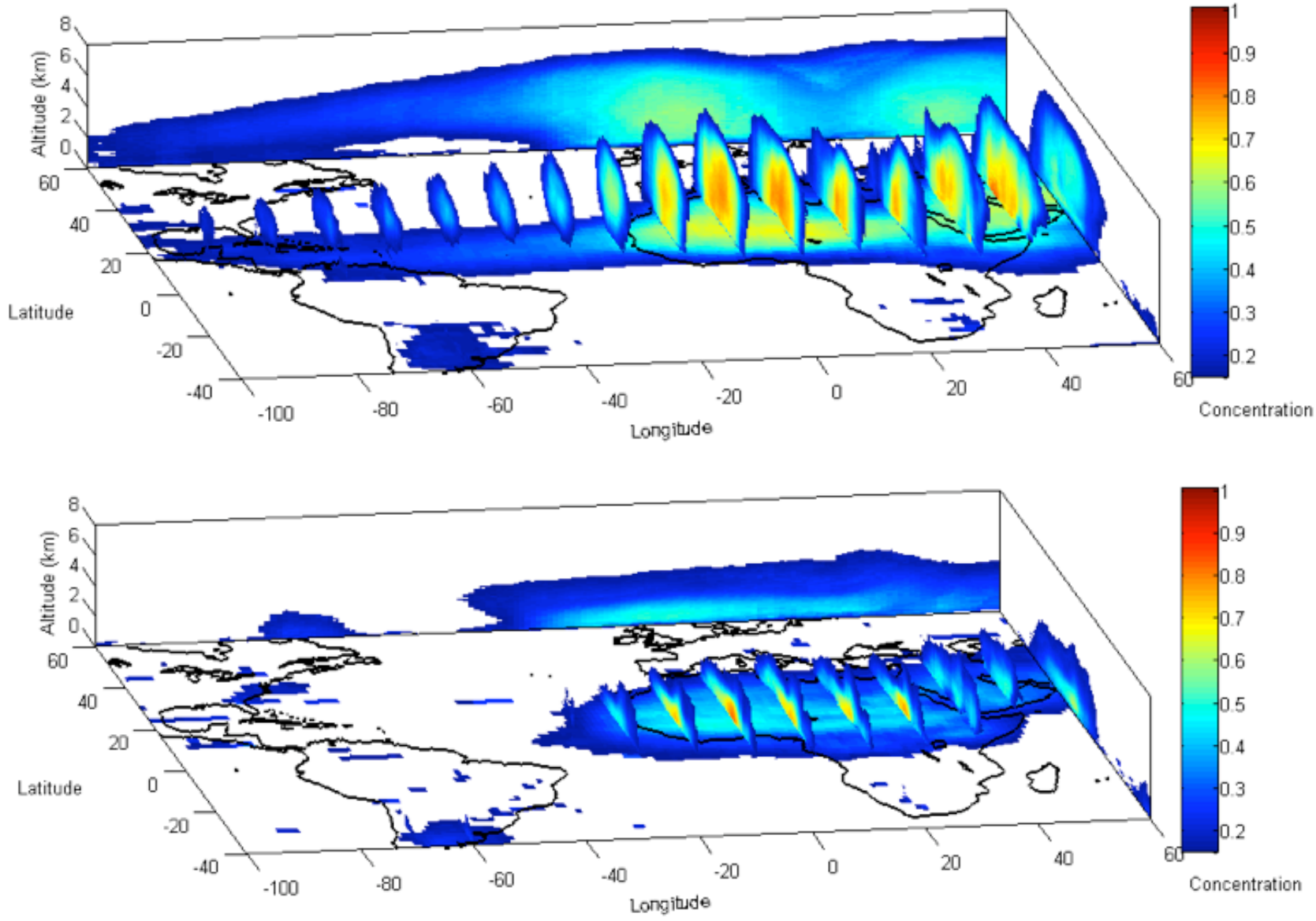


Figure 12. Schematic longitudinal vertical cross section along the Atlantic dust corridor with general characteristics of dust front and its associated changes in meteorological fields. Wind directions are illustrated as the solid arrows. The transport speed of the dust event is marked in the striped left arrow. The Bodélé Depression is used as a representative of African dust sources. The thick red line marks the ground level and denotes the centerline of a 20° latitude (10° to the north and 10° to the south) meridonal range used for the zonal vertical profile calculation.



Credit of Aaron Adams @ RSMAS, Univ. of Miami

Summary & Discussions

1. Extreme African dust outbreak day occurred almost once a week on average in these 5 years (roughly 65 events per year). **Dust and dry air outbreaks** can be closely associated with each other sometimes but they **can occur independently**.
2. The **Bodélé Depression** is dominant in boreal winter although it is active throughout much of the year. In boreal spring, summer, and autumn, the majority of dust outbreaks reach the **West Indies**. Some go northwards to the **southeastern US**. In boreal spring and winter, dust outbreaks shift southward and most reach the northeast coast of **South America**. A few events go northwards to **Europe**.
3. Dust outbreaks travel westward at an approximate speed of **8°–10° longitude(~1000 km) a day**. From the coast of West Africa it takes about five days for outbreaks to reach Barbados and a week or so the Caribbean and Gulf of Mexico and the southeastern United States. About half of the dust outbreaks retain **their identities over the Atlantic after 7 days**.
4. **Dust layer height are consistent with the vertical structures of the dry and warm layers identified from the water vapor and temperature profiles**, **which are mainly in the lower troposphere**. It indicates that African dust layers are one of the factors modulating the moisture content and static stability in the climate system over the north tropical Atlantic.
5. **Satellite data uncertainties** are the main limitations to works of this kind. Such observational evidence are useful to testing numerical simulations of African dust genesis and transport.

THANKS!

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Huang, J., C. Zhang, and J. M. Prospero (2010), **African dust outbreaks**: A satellite perspective of temporal and spatial variability over the tropical Atlantic Ocean, ***J. Geophys. Res.***, *115, D05202, doi:10.1029/2009JD012516.*